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LAKESHORE REVEGETATION STUDIES AT LAKE OAHE, SOUTH DAKOTA

by

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A 4-year study was conducted to assess the flood tolerance of plant species selected as potentially useful in revegetating shorelines of fluctuating water-level reservoirs. The study employed a subimpoundment adjacent to Lake Oahe, S. Dak., to systematically inundate 55 transplanted species. Survival and growth of each species were monitored regularly.

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20. ABSTRACT (Continued).

Eight plant species demonstrated sufficiently consistent responses to inundation to merit recommendations for planting in specific shoreline environments. Fourteen additional species showed some degree of flood tolerance and are recommended for trial plantings in particular circumstances. Of all the species tested, ***Phalaris arundinacea*** is by far the best candidate for a wide range of shoreline site conditions in the northern prairie region.

The Lake Oahe study also suggested that, in planning a shoreline project, careful assessments of species characteristics, substrate type and configuration, and wind and wave action be made prior to any field effort. Further, a successful transplanting operation must include careful attention to the newly planted vegetation during the critical establishment period.

PREFACE

This report was prepared as part of the Environmental and Water Quality Operational Studies (EWQOS) Program, Task IIE.1, "The Environmental Effects of Fluctuating Reservoir Water Levels." The EWQOS Program is sponsored by the Office, Chief of Engineers (OCE), US Army, and is assigned to the US Army Engineer Waterways Experiment Station (WES), under the purview of the Environmental Laboratory (EL). The OCE Technical Monitors were Mr. Earl Eiker, Dr. John Bushman, and Mr. James L. Gottesman. Dr. J. L. Mahloch was the WES Program Manager of EWQOS.

The original concept for this research was developed by Mr. Hollis H. Allen of the Wetlands and Terrestrial Habitat Group (WTHG), EL. The fieldwork was directed by Dr. George R. Hoffman, Department of Biology, University of South Dakota, Vermillion, under Contract No. DACW78-C-0116. This report was prepared by Dr. Stephen G. Shetron, Mr. Charles V. Klimas, and Mr. Allen, WTHG, based on annual reports supplied by Dr. Hoffman. Mr. David Kadlecek, Resource Manager, Lake Oahe, and the US Army Engineer District, Omaha, provided valuable assistance throughout the course of this study.

The work was conducted under the direct supervision of Mr. Allen and Dr. Hanley K. Smith, Chief, WTHG, and under the general supervision of Dr. Conrad J. Kirby, Jr., Chief, Environmental Resources Division, and Dr. John Harrison, Chief, EL.

At the time of publication of this report, COL Allen F. Grum, USA, was Director of WES and Dr. Robert W. Whalin was Technical Director.

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CONTENTS

	Page
PREFACE	1
PART I: INTRODUCTION	3
Background	3
Study Area	3
PART II: METHODS AND MATERIALS	5
Site Preparation	5
Transplanting and Treatment	5
Transplant Performance Monitoring	7
PART III: RESULTS	9
PART IV: DISCUSSION	12
PART V: SUMMARY	16
APPENDIX A: SCIENTIFIC AND COMMON PLANT NAMES USED IN TEXT	A1
Herbaceous Species	A1
Woody Species	A2

LAKESHORE REVEGETATION STUDIES AT LAKE OAHE, SOUTH DAKOTA

PART I: INTRODUCTION

Background

1. Studies were conducted at Lake Oahe, S. Dak., from June 1979 through September 1982 to evaluate selected plant species for inundation tolerance. This work was prompted by the need to revegetate the typically denuded shores of fluctuating water-level reservoirs. Such bare shore areas are often conducive to erosion, are unsightly, and as fish and wildlife habitat are much less valuable than vegetated shores. As an initial approach toward developing revegetation guidelines for reservoirs of the northern prairie region of the United States, the flood-tolerance field trials described herein were initiated. Over the four growing periods of this study, 38 herbaceous and 17 woody plant species were tested in a subimpoundment adjacent to Lake Oahe.

Study Area

2. Lake Oahe was formed following closure of Oahe Dam in 1958 and reached maximum pool level in 1971. It extends from south of Bismarck, N. Dak., to north of Pierre, S. Dak. (Figure 1). The lake occupies the former floodplain-river terrace complex of the Missouri River as well as considerable former upland areas never flooded before the formation of the reservoir. Lower parts of major tributaries, the Cheyenne, Moreau, Grand, and Cannonball Rivers, are also part of the lake. Average annual water fluctuation (1971-1974) was 3.6 m.

3. A continental climate characterizes the study area, with wide seasonal temperature fluctuations. Mean annual rainfall is approximately 40 cm, and mean annual temperature is approximately 8.7° C at Pierre, S. Dak., near the study site.

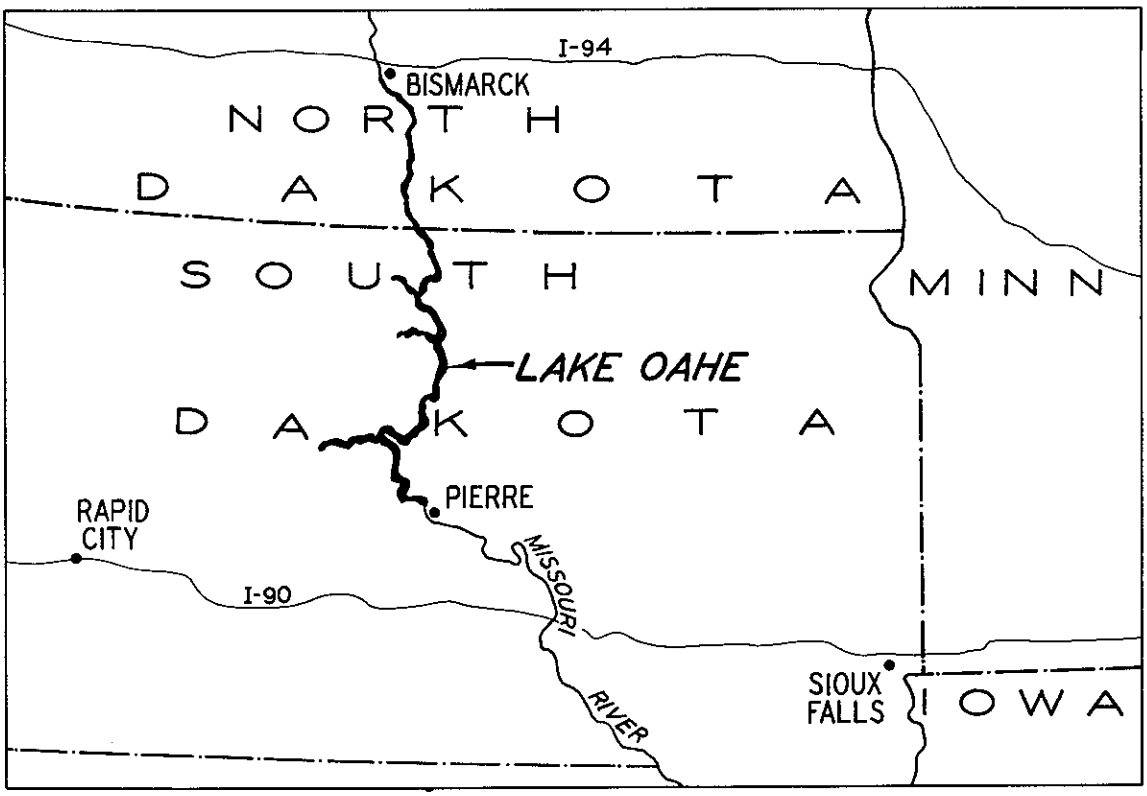

Figure 1. Regional map

4. Cretaceous Pierre Shale is the dominant geologic formation surrounding the southern two-thirds of the lake, while sandstones are more common to the north. Pleistocene glacial deposits occur commonly, and where these have undergone wave erosion, the shoreline is often armored with large stones or boulders. Soils derived from the Pierre Shale contain much clay, while those formed from sandstone and glacial deposits are lighter textured.

5. Typical upland vegetation of the study region is grassland dominated by *Agropyron smithii, Stipa viridula, Stipa comata,* and *Bouteloua gracilis.* Woody species are largely restricted to protected slopes or river floodplains. The banks of the lake support very little perennial vegetation due to the effects of fluctuating water levels and intensive grazing.

PART II: METHODS AND MATERIALS

Site Preparation

6. An abandoned oxbow of Spring Creek, located approximately 9.7 km northwest of Oahe Dam near the confluence of Spring Creek and Lake Oahe, served as the subimpoundment for this study. Dikes and water-level regulation equipment were installed to permit controlled filling and release of water from the pool. Slopes within the pool were graded to approximately 1:6, and the area was fenced to exclude livestock.

7. Soil samples taken from the impoundment were loams with adequate nutrients for the study. The site was disked, and plot locations were established prior to planting. Plot layout consisted of four replicates, each made up of five elevational tiers of plots. Each tier contained an array of herbaceous species plots (122.0 cm by 40.6 cm) and an array of woody species plots (183 cm by 183 cm). Plots were permanently marked with steel corner stakes, and walkways were left between tiers.

Transplanting and Treatment

8. During the first year of the study, 14 herbaceous and 7 woody species were planted. Species and planting stock are listed in Table 1. During each subsequent year, new species were introduced to replace those that failed to tolerate inundation. Successful species were left in place and monitored the following year or years. In all, 55 species were planted at the site. Species were planted by hand. Herbaceous species were planted on 20-cm centers, 10 per plot, in a 2 by 5 arrangement. Woody species were planted on 61-cm centers, 9 per plot, in a 3 by 3 arrangement. Transplants were irrigated thoroughly and allowed to establish for at least 2 weeks prior to any inundation treatment. Plots were weeded as necessary to reduce competition from annual weeds, except in check plots maintained in each tier to monitor invasion by and

Table 1

Species Tested at Lake Oahe

Species	Year Introduced	Planting Stock*
Herbaceous		
Acorus calamus	1981	r
Agropyron elongatum	1979	s
Agropyron intermedium	1979	s
Agropyron repens	1982	s
Agropyron smithii	1979	s
Agropyron trachycaulum	1979	s
Alopecurus arundinaceus	1979, 82	s
Andropogon gerardi	1980	s
Andropogon scoparius	1980	s
Buchloe dactyloides	1979	s
Elymus junceus	1982	s
Festuca rubra	1982	s
Glycerrhiza lepidota	1982	s
Iris versicolor	1981	r
Lolium officinale	1982	s
Lolium perenne	1982	s
Nasturtium officinale	1981	s
Panicum virgatum	1980	s
Peltandra virginica	1981	s
Phalaris arundinacea	1979	s
Phleum pratense	1982	s
Phragmites australis	1979	r
Poa pratensis	1979	s
Polygonum coccineum	1979	r
Polygonum pensylvanicum	1981	s
Pontederia cordata	1981	r
Sagittaria latifolia	1981	r
Scirpus acutis	1981	r
Scirpus americanus	1979	r
Scirpus fluviatilis	1981	r
Scirpus paludosus	1981	s
Scirpus validus	1979	r
Sorghastrum avenaceum	1980	s
Sorghum sudanense	1982	s
Sparganium eurycarpum	1981	r
Spartina pectinata	1979	s
Stipa viridula	1980	s

(Continued)

* r = roots, rhizomes, tubers, etc.
s = potted seedlings.
br = bare root stock (3-9 dm tall).

Table 1 (Concluded)

Species	Year Introduced	Planting Stock
Herbaceous (Continued)		
Typha latifolia	1979, 81	r
Zizania aquatica	1981	s
Woody		
Acer negundo	1980	br
Acer saccharinum	1982	br
Alnus glutinosa	1979	br
Cornus stolonifera	1979, 80	br
Fraxinus pennsylvanica	1979, 80	br
Populus alba	1982	br
Populus balsamifera		br
X *deltoides*	1982	br
Populus canadensis		
eugenei	1982	br
Populus deltoides	1979, 80	br
Salix acutifolia	1982	br
Salix amygdaloides	1979	br
Salix lutea	1980	br
Salix rigida	1980	br
Shepherdia argentea	1979	br
Symphoricarpos albus	1979	br
Quercus macrocarpa	1980	br

survival of "volunteer" species. A severe grasshopper infestation in 1981 was controlled with an insecticide.

9. Treatments were periods of inundation--0, 2, 4, 6, and 8 weeks--from the top tier (tier 1), which was not flooded, to the bottom tier (tier 5), which was flooded for 8 weeks. About mid-July the pool was filled to cover tiers 2 through 5. Every 2 weeks the water level was lowered to expose another tier (Table 2). Because of record-low water levels in Lake Oahe in 1981, the investigators were unable to flood any tier of plants. This confounded the results but was realistic in terms of water-level conditions in the lake and influence on the shore environment.

Transplant Performance Monitoring

10. To evaluate the survival and performance of each species, a

Table 2

Sumary of Inundation Regime in the Lake Oahe Study

Tier	Period of Inundation	Days	Weeks
	1979		
1	--	--	--
2	18 Jul-1 Aug	15	2
3	18 Jul-15 Aug	29	4
4	18 Jul-29 Aug	43	6
5	18 Jul-12 Aug	57	8
	1980		
1	--	--	--
2	15 Jul-3 Aug	20	3
3	15 Jul-18 Aug	35	5
4	15 Jul-30 Aug	47	7
5	15 Jul-15 Sep	63	9
	1982		
1	--	--	--
2	15 Jul-1 Aug	18	2.5
3	15 Jul-15 Aug	32	4.5
4	15 Jul-1 Sep	48	7
5	15 Jul-15 Sep	63	9

NOTES: Tier 1 was not inundated.
No data for 1981 because water levels in Lake Oahe were too low to fill the subimpoundment.

variety of measurements were made for all plots prior to inundation and after each drawdown. The number of surviving plants and their average height were recorded for each plot. Cover of herbaceous plots was estimated using a 2- by 5-dm plot frame placed across the top one-fifth, the middle, and the bottom one-fifth of each plot. Canopy cover of woody plots was measured by extending a tape through the center of each plot and recording canopy interceptions. Vigor (reflecting state of growth or decline) and vitality (reflecting reproductive condition) ratings were assigned to each plot.

PART III: RESULTS

11. Rigorous statistical analyses of the results of the Lake Oahe study were precluded by (a) the lack of a 1981 drawdown, (b) unequal treatments among species (planted different years), and (c) unequal erosion and sedimentation among tiers. Nevertheless, most of the species evaluated can be considered to have had a fair test of their capacity to withstand the principal stresses imposed in a shore environment. The performance of those species showing sufficient tolerance of the experimental conditions to merit consideration in revegetation programs is reviewed in the following paragraphs. Some of the species tested that performed poorly may well be appropriate for shoreline applications elsewhere. In this study, 1981 was the year to test a number of aquatic species. The investigators could not predict the record-low water conditions that very likely killed the transplants.

12. The following species were all planted in 1979 and persisted throughout the 4-year study. Their performance indicates they should be suitable for use in shoreline revegetation projects within the inundation-duration limitations given for each species. Plot coverage is used here as the principal criterion of herbaceous species' success, while simple transplant survival provides the best indicator of woody species' flood tolerance.

13. Recommended herbaceous species are described below.

a. *Buchloe dactyloides* proved to be intolerant of flood durations exceeding 2 weeks, despite good survival with up to 6 weeks of inundation during the first year of study. This species was steadily eliminated from the lower tiers as the experiment progressed until, in 1982, it was present only in the upper two tiers, where it maintained approximately 50-percent cover.

b. *Phalaris arundinacea* was the most successful species tested in this study. It tolerated the full range of inundation treatments and also survived well through 1981 when shore substrates were extremely dry. By the end of 1982, this species had achieved total or near-total coverage of all plots receiving up to 6 weeks of inundation. While its coverage was reduced somewhat by the 8- to 9-week inundation each year, it invariably recovered before the next season.

c. *Phragmites australis* was very slow to establish and, at the end of 1979, its maximum coverage was 30 percent in any tier. Coverage declined further in the lowest two tiers after the 1979 season, but gained steadily in all tiers after that. By the end of the 1982 season, this species approached 100-percent cover in the 2- and 4-week flood zones, 60-percent cover in the unflooded tier, 30-percent cover in the 6-week zone, and 4-percent cover in the 8- to 9-week zone.

d. *Poa pratensis* declined steadily in the lower tiers and was present only in tiers 1 and 2 by the end of 1982. While coverage remained low, this species persisted sufficiently in the 2-week flood zone to merit consideration for applications where only minimal and occasional inundation is anticipated.

e. *Scirpus americanus* performed best in the 2- and 4-week flood zones, where coverage at the end of 1982 was 25 and 47 percent, respectively. Coverage was lower in the unflooded and 6-week tiers, and the species was completely eliminated from the 8- to 9-week flood zone.

f. *Spartina pectinata* increased in coverage in most tiers during the period of inundation, and this species maintained good coverage in all but the lowest tier throughout the study. At the end of 1982, tiers 1, 2, 3, and 4 had coverages of 72, 66, 49, and 16 percent, respectively. This species persisted in the 8- to 9-week flood zone until 1982, but coverages were low in previous years.

14. Recommended woody species are described below.

a. *Fraxinus pennsylvanica* performed well with up to 4 weeks of flooding and persisted to some extent in the 6-week inundation zone. After 4 years, this species had better than 95-percent survival among the original transplants in tiers 1, 2, and 3. Tier 4 (6 weeks of flooding) also had better than 95-percent survival at the end of the 1980 season, but survival declined to near 50 percent by the end of 1982. No survivors remained in tier 5 (8 to 9 weeks of flooding). By the end of 1982, trees in tiers 1 and 2 were approaching 200 cm in height.

b. *Populus deltoides* was the only other woody species that was consistently successful in this study, although it did not perform as well as *Fraxinus*. At the end of 1982, the 1979 transplants showed approximately 50-percent survival in tiers 1 and 2 and 25 percent in tier 3. A few individuals remained in tier 4, but all had been eliminated from the lowest tier. Height growth was over 400 cm in the unflooded tier, over 300 cm in the tier flooded 2 weeks, and over 200 cm in the 4-week inundation zone.

15. Other species planted in 1980 and 1982 were subjected to limited inundation treatments and therefore could not be fully evaluated. Nevertheless, species that survived at least 2 weeks of inundation are listed in Table 3. No volunteer species were sufficiently successful to merit recommendation as candidates for revegetation projects.

Table 3

Additional Species Capable of Tolerating at Least 2 Weeks of Growing Season Inundation

Herbaceous Species	Woody Species
Alopecurus arundinaceus	*Acer negundo*
Andropogon gerardi	*Acer saccharinum*
Panicum virgatum	*Cornus stolonifera*
Sorghastrum avenaceum	*Populus alba*
Sorghum sudanense	*Populus balsamifera* X *deltoides*
	Populus canadensis
	Quercus macrocarpa
	Salix acutifolia
	Salix lutea

PART IV: DISCUSSION

16. Although a number of species showed some tolerance to flooding, only eight of those planted in 1979 survived long enough to permit specific recommendations regarding their suitability for revegetating shores. The general tolerance range of each of the eight species is indicated in Figure 2, but it should be noted that the simple hydrologic regime descriptor "weeks of inundation" actually reflects a complex of environmental factors that should be considered in planning a revegetation project.

	Inundation Tolerance Range, weeks
Species	0 2 4 6 8
Herbaceous	
Buchloe dactyloides	———
Phalaris arundinacea	———————————
Phragmites australis	———————————
Poa pratensis	———————
Scirpus americanus	———————————
Spartina pectinata	———————————
Woody	
Fraxinus pennsylvanica	———————————
Populus deltoides	———————————

Figure 2. Inundation tolerance of eight species, as indicated by Lake Oahe flooding trials

For example, among the herbaceous species, height is clearly related to survival, with taller species generally tolerating more inundation than shorter species. It appears that this is a reflection of inundation depth; that is, species capable of maintaining some portion of their stems above water tolerate flooding of the substrate better than those totally submersed. Thus, the very tall species *Phalaris arundinacea* and *Phragmites australis* were much more successful under extended (deep) flooding than the low-growing *Buchloe dactyloides* and *Poa pratensis*.

17. For woody species, this height and submersion factor has implications for the selection or preparation of transplants. Where the intended planting site is subject to deep flooding, transplants should be tall enough to ensure that they will protrude above water level for most of the first growing season. If they survive the first season, increased height growth should ensure that they are not subject to complete submersion in subsequent seasons.

18. Another aspect of tolerance to shoreline conditions concerns the response of plants to periods of extended drawdown. Drought tolerance may be as important a characteristic as flood tolerance in the shoreline environment. Flood control reservoirs often draw down in a pattern that leaves the fluctuation zone exposed during the hottest and driest summer months. Thus, plants that have just emerged from the stressful flooding conditions may then be exposed to a prolonged period of inadequate soil moisture. In some years, regional conditions may result in unusually low reservoir water levels, leaving the transplants unflooded entirely, as happened in 1981 in this study. While most of the species listed in Figure 2 were capable of tolerating such dry conditions, some (notably *Scirpus americanus*) performed better in moderately inundated zones than in the unflooded tier.

19. Another aspect of shoreline inundation that may influence plant survival concerns erosion and sedimentation. Within the experimental pool at Lake Oahe, the loose alluvium on the pool slope tended to shift downslope, exposing stony glacial till in the middle tiers and causing a buildup of sediment in the bottom tier. It is difficult to assess the importance of this soil deposition as a factor contributing to the very low survival rates in the 8- to 9-week tier, but it was an added stress on plants already subjected to severe flooding. The erodibility of soils and slope configurations should be considered in determining suitable planting sites and the type of site preparation appropriate to a given revegetation effort.

20. Aside from height and flood/drought tolerance considerations, other factors that should be assessed in selecting species for revegetation efforts relate to the growth habits of the plants. Where wave

action is anticipated to be a problem, species forming thick resistant roots and rhizomes are preferable to caespitose grasses and single-stemmed forbs having less tenacious and more erodible root systems. For example, Hoffman (1982)* noted that *Phalaris arundinacea*, which forms dense colonies, successfully withstands wave action where it occurs along the shores of Lake Oahe. The stout, rapidly creeping rhizomes of *Phragmites australis* suggest it would be similarly resistant and appropriate for similar environments.

21. The relationship between growth habit and site conditions should also be assessed where woody plants are being considered for introduction to the shoreline environment. In the northern Great Plains, upland vegetation is predominantly grassland. Forests and woodlands are confined to riparian habitats and to those upland habitats where combinations of soil and topography permit greater-than-average accumulations of soil moisture. While it may be desirable to plant trees in various recreational areas around these prairie lakes, the greatest difficulty is desiccation as a result of low soil moisture and drying winds. Results of this study indicate that some woody species will survive shore environments if the substrate moisture can be controlled.

22. The success of many of the species introduced in 1979 and the failure of most of the 1981 species illustrates the importance of ensuring good conditions for establishment immediately following transplanting. The 1979 transplants were thoroughly irrigated and allowed to initiate new root growth prior to the beginning of inundation treatments. In 1981, water was not available for irrigation and flooding did not occur; thus, the newly transplanted aquatic species could not be tested adequately. Where a large investment of effort and funds is planned for a revegetation project, it is prudent to make contingency plans for the rapid provision of irrigation water if necessary. In any case, thorough watering of new transplants should be regarded as a basic component of any revegetation effort. Regular monitoring of transplants should

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* Hoffman, G. R. 1982. "Revegetation of Lake Oahe Shore End-of-Year Report 1982" (File Report), Department of Biology, University of South Dakota, Vermillion, 35 pp.

include detecting drought stress before serious transplant mortality occurs.

PART V: SUMMARY

23. The Lake Oahe shoreline revegetation study was successful in identifying plant species capable of withstanding the stresses imposed by water-level fluctuations in reservoirs of the northern Great Plains. Of 55 species tested, eight species survived the entire 4 years and thus allowed specific recommendations regarding their applicability in shore revegetation projects. Of these, *Phalaris arundinacea* was clearly best suited for a wide range of inundation conditions (up to 8 to 9 weeks of flooding). At least 14 other species showed some degree of tolerance to the shore environment, but because they survived much shorter inundation periods, they can be recommended for limited and specific use in this environment. However, these species are considered good candidates for trial introductions where inundation periods are very limited, and large-scale plantings may be recommended only after at least 3 years of monitoring.

24. The Lake Oahe study also showed the importance of considering a variety of factors other than simple flood tolerance in selecting sites and species for revegetation projects. Drought tolerance is an important component of species suitability to the shoreline environment, since low-water years and normal operational drawdowns may expose transplants to extremely dry conditions in midsummer and late summer. Slope steepness should also be considered, as it influences depth of flooding and erosion/siltation processes. Exposure to wave action may dictate the selection of plant species adapted to such situations by virtue of their dense growth habits and erosion-resistant stem/root structures. In most cases, revegetation projects should rely on a mixture of species, each suited to particular combinations of site conditions. The success of the project also depends on careful planning, planting when soil moisture is adequate, and close attention to the condition of transplants during the period of critical establishment.

APPENDIX A: SCIENTIFIC AND COMMON PLANT NAMES USED IN TEXT

Scientific Name	Common Name
Herbaceous Species	
Acorus calamus	Sweet flag
Agropyron elongatum	Tall wheatgrass
Agropyron intermedium	Intermediate wheatgrass
Agropyron repens	Quackgrass
Agropyron smithii	Western wheatgrass
Agropyron trachycaulum	Slender wheatgrass
Alopecurus arundinaceus	Foxtail (creeping)
Andropogon gerardi	Big bluestem
Andropogon scoparius	Little bluestem
Bouteloua gracilis	Blue grama
Buchloe dactyloides	Buffalo grass
Elymus junceus	Russian wildrye
Festuca rubra	Red fescue
Glycerrhiza lepidota	Wild licorice
Iris versicolor	Blue flag
Lolium officinale	Ryegrass
Lolium perenne	Perennial wildrye
Nasturtium officinale	Water cress
Panicum virgatum	Switchgrass
Peltandra virginica	Arrow arum
Phalaris arundinacea	Reed canary grass
Phragmites australis	Common reed
Phleum pratense	Timothy
Poa pratensis	Kentucky bluegrass
Polygonum coccineum	Smartweed
Polygonum pennsylvanicum	Pinkweed, smartweed
Pontederia cordata	Pickerel weed
Sagittaria latifolia	Duck potato
Scirpus acutis	Great bullrush
Scirpus americanus	Sword grass
Scirpus fluviatilis	River bullrush
Scirpus paludosus	Salt marsh bullrush
Scirpus validus	Soft stem bullrush
Sorghastrum avenaceum	Indian grass
Sorghum sudanense	Sudan grass (Piper)
Sparganium eurycarpum	Broadfooted burreed
Spartina pectinata	Prairie cordgrass
Stipa comata	Needle and thread
Stipa viridula	Green needlegrass
Typha latifolia	Broadleaf cattail
Zizania aquatica	Wild rice

Woody Species

Acer negundo	Box elder
Acer saccharinum	Silver maple
Alnus glutinosa	European alder
Cornus stolonifera	Red-osier dogwood
Fraxinus pennsylvanica	Green ash
Populus alba	White poplar
Populus balsamifera X *deltoides*	Northwest poplar
Populus canadensis eugenei	Imperial poplar
Populus deltoides	Eastern cottonwood
Salix acutifolia	Sharp leaf willow
Salix amygdaloides	Peach leaf willow
Salix lutea	Yellow willow
Shepherdia argentea	Buffalo berry
Symphoricarpos albus	Coral berry
Quercus macrocarpa	Bur oak